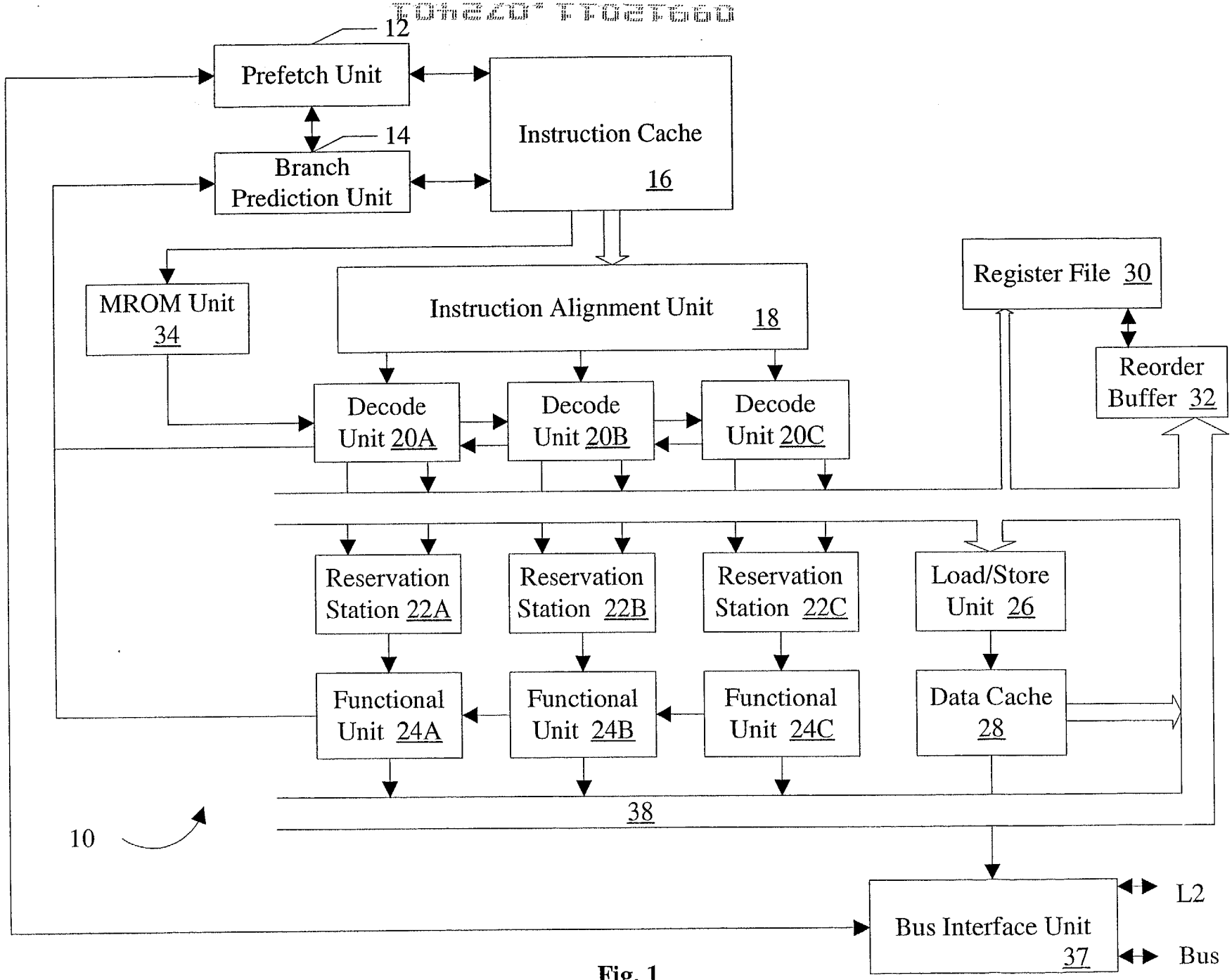

12
Prefetch Unit
14
Branch Prediction Unit
Instruction Cache 16
MROM Unit 34
Instruction Alignment Unit 18
Register File 30
Reorder Buffer 32
Decode Unit 20A
Decode Unit 20B
Decode Unit 20C
Reservation Station 22A
Reservation Station 22B
Reservation Station 22C
Load/Store Unit 26
Functional Unit 24A
Functional Unit 24B
Functional Unit 24C
Data Cache 28
38
10
Bus Interface Unit 37
L2
Bus

Fig. 1

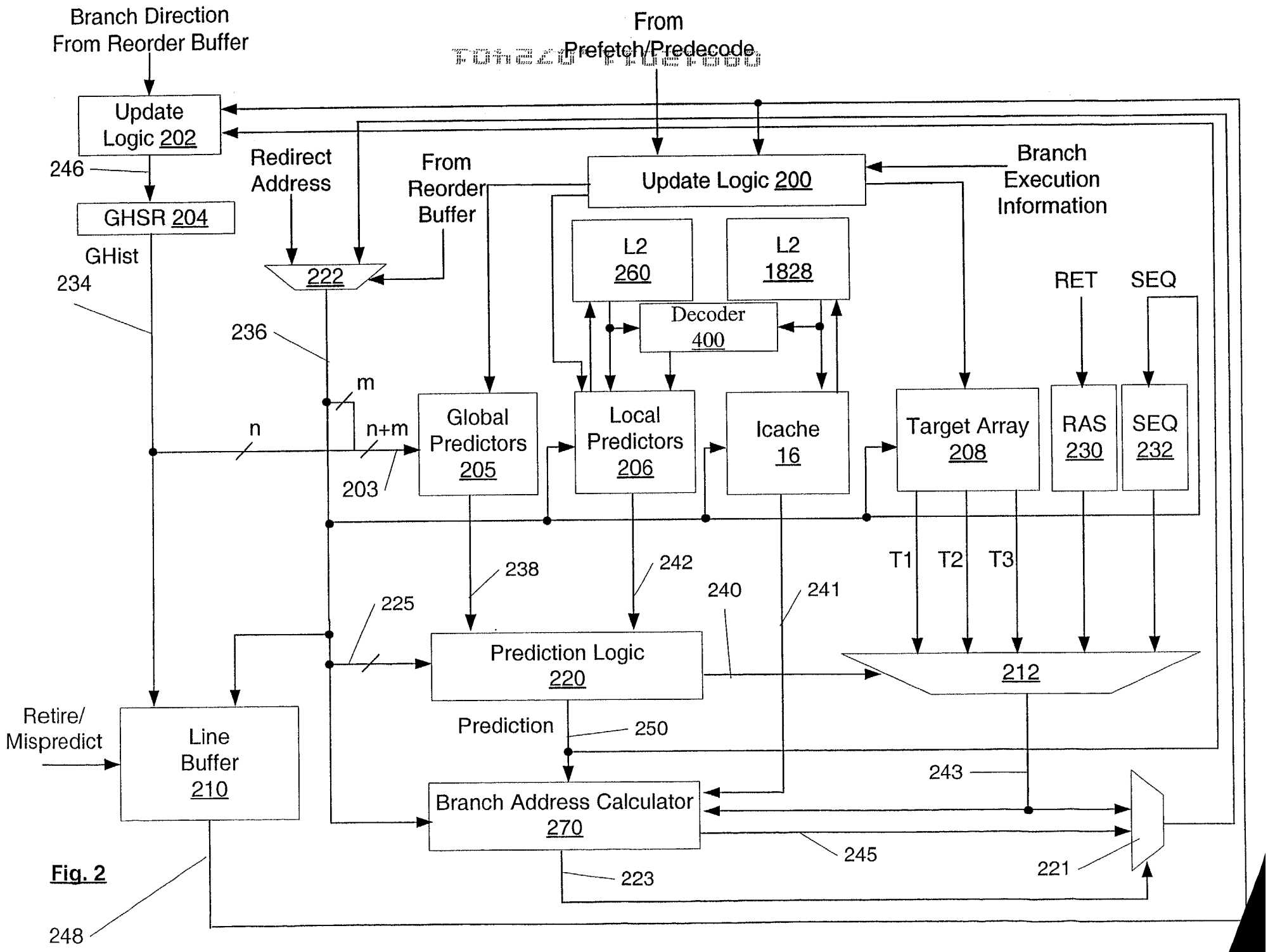

Branch Direction From Reorder Buffer
From Prefetch/Predecode
Update Logic 202
246
GHSR 204
GHist
234
Redirect Address
From Reorder Buffer
222
Update Logic 200
Branch Execution Information
L2 260
L2 1828
Decoder 400
RET
SEQ
236
m
n
n+m
203
Global Predictors 205
Local Predictors 206
Icache 16
Target Array 208
RAS 230
SEQ 232
T1
T2
T3
238
242
240
241
225
Prediction Logic 220
212
Retire/ Mispredict
Line Buffer 210
Prediction
250
243
Branch Address Calculator 270
245
221
223
248

Fig. 2

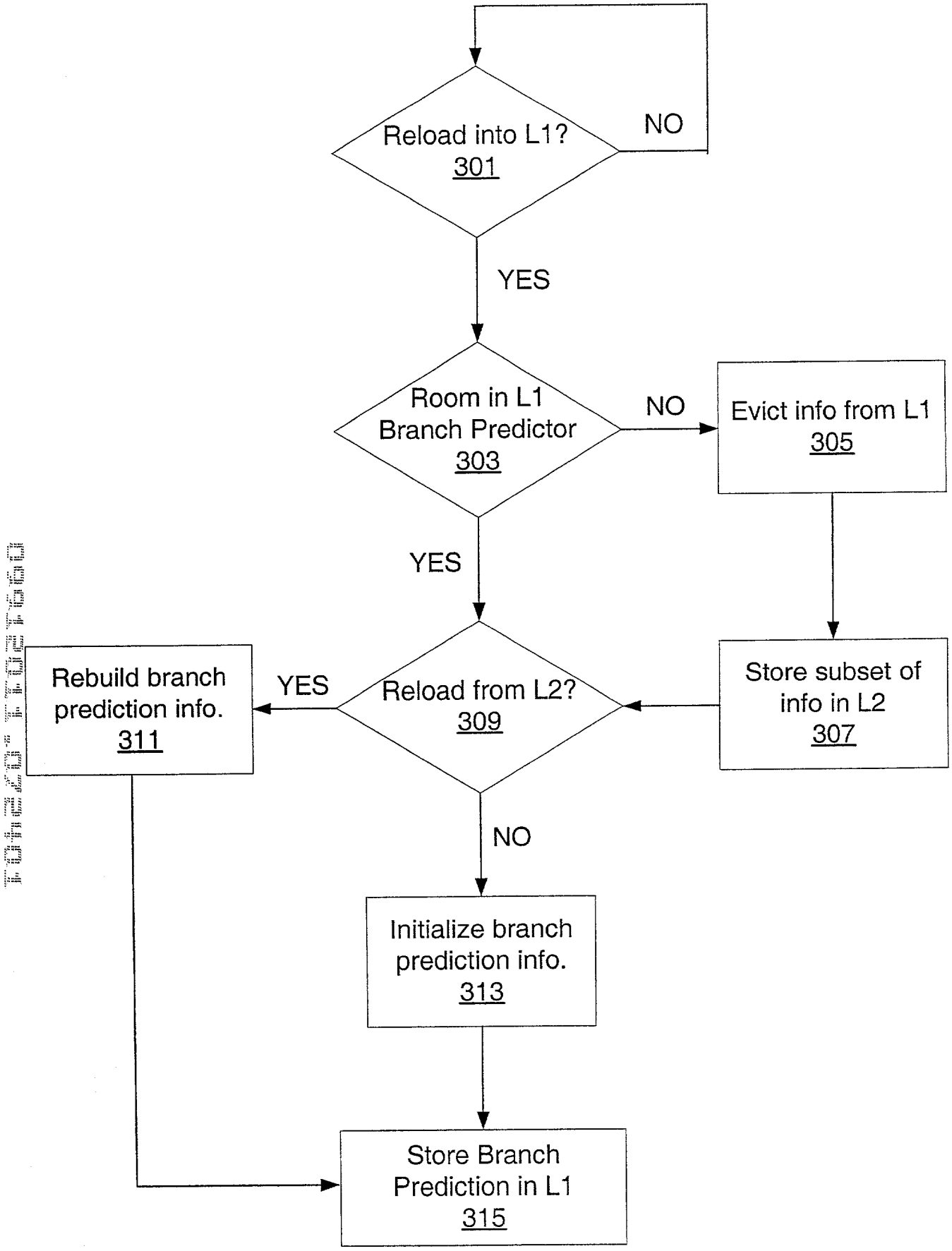

Reload into L1?
301
NO
YES
Room in L1
Branch Predictor
303
NO
Evict info from L1
305
YES
Rebuild branch
prediction info.
311
YES
Reload from L2?
309
Store subset of
info in L2
307
NO
Initialize branch
prediction info.
313
Store Branch
Prediction in L1
315

Fig. 3

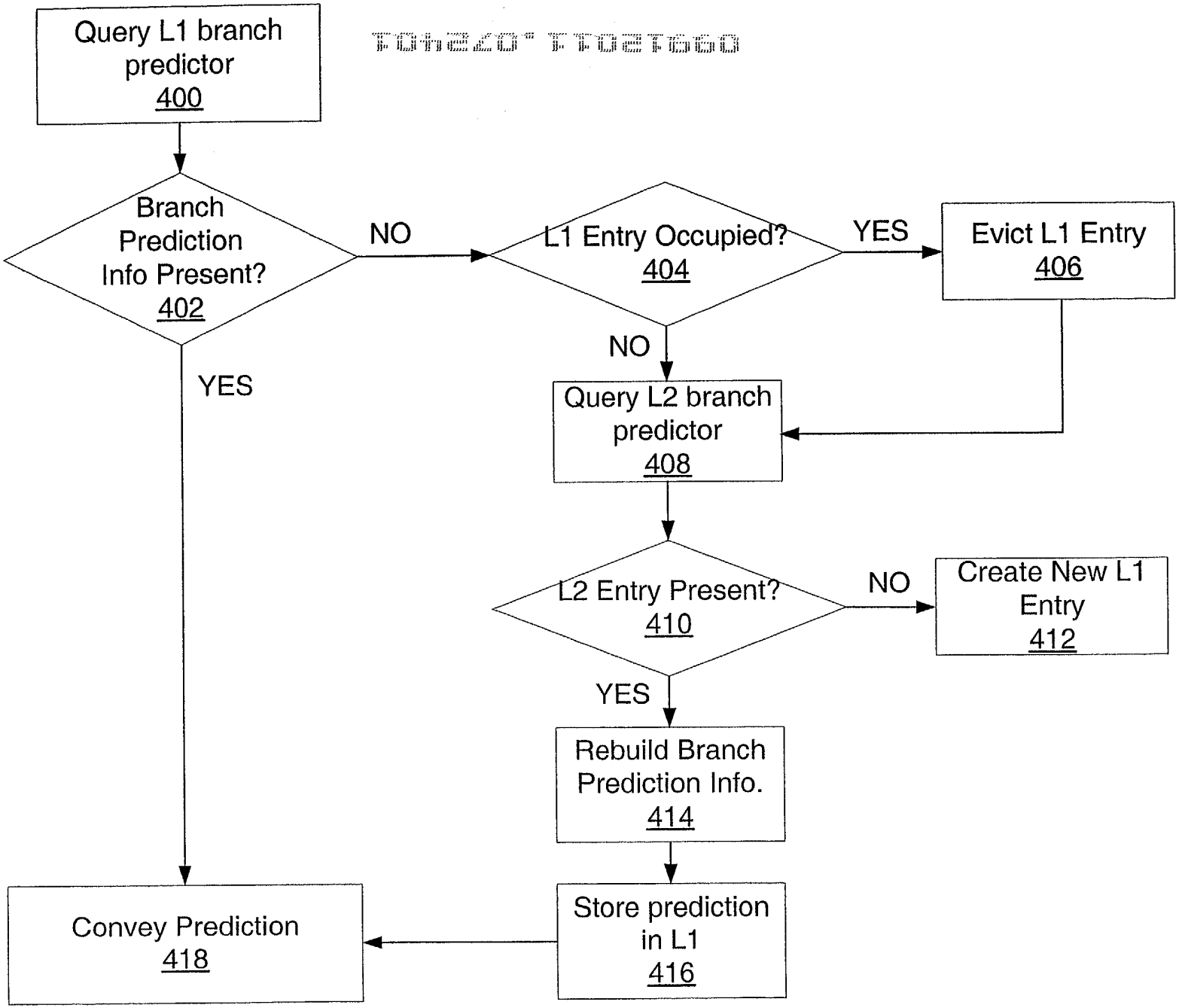

Query L1 branch predictor 400
Branch Prediction Info Present? 402
NO
L1 Entry Occupied? 404
YES
Evict L1 Entry 406
NO
YES
Query L2 branch predictor 408
L2 Entry Present? 410
NO
Create New L1 Entry 412
YES
Rebuild Branch Prediction Info. 414
Store prediction in L1 416
Convey Prediction 418

Fig. 4

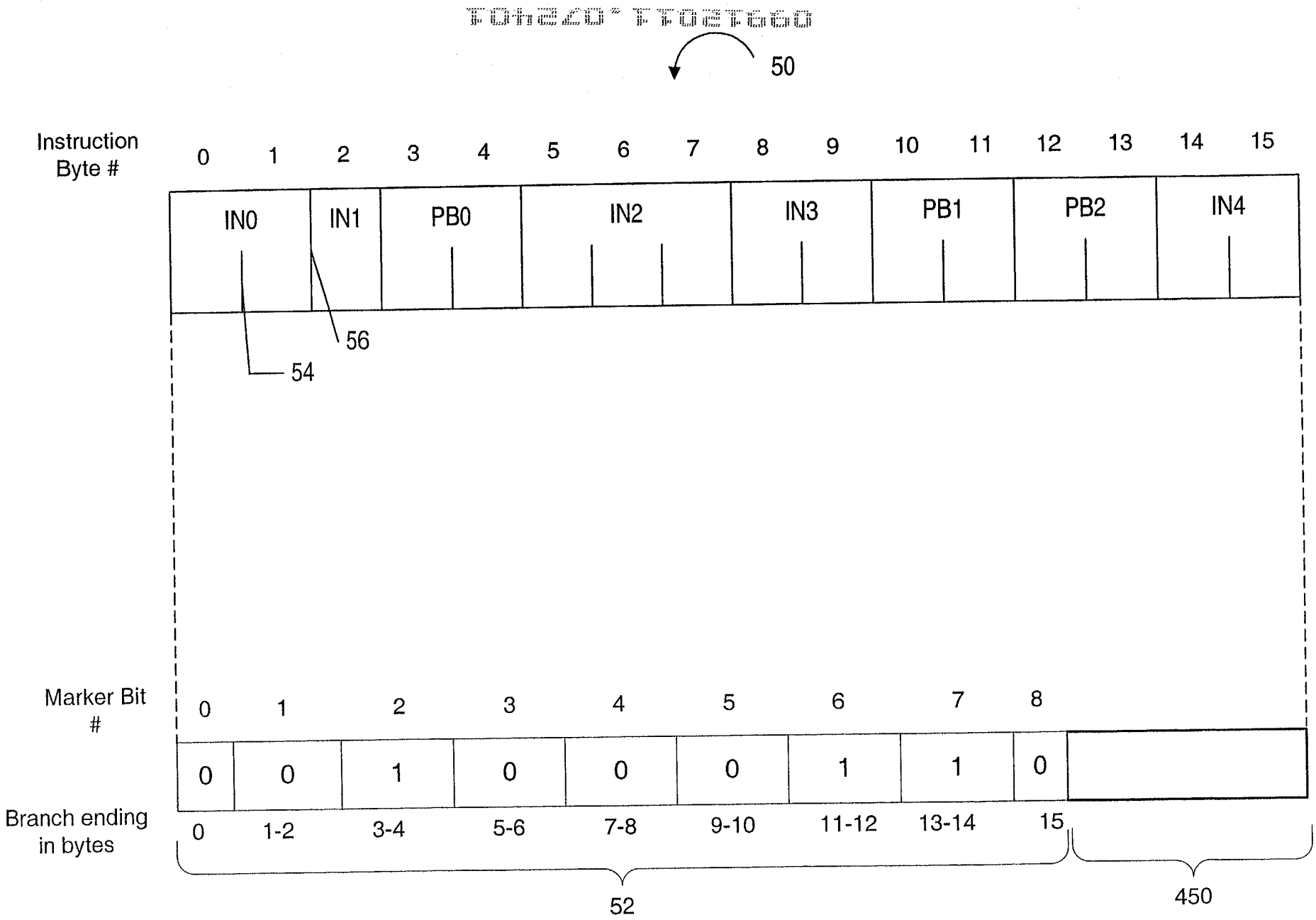

50
Instruction Byte #
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
IN0
IN1
PB0
IN2
IN3
PB1
PB2
IN4
54
56
Marker Bit #
0 1 2 3 4 5 6 7 8
0 0 1 0 0 0 1 1 0
Branch ending in bytes
0 1-2 3-4 5-6 7-8 9-10 11-12 13-14 15
52
450

Fig. 5

	602	604	606	608	610	612	614	616	618
Offset	<=0	<=1	<=3	<=5	<=7	<=9	<=11	<=13	<=15
Marker Bit #	0	1	2	3	4	5	6	7	8

Fig. 6

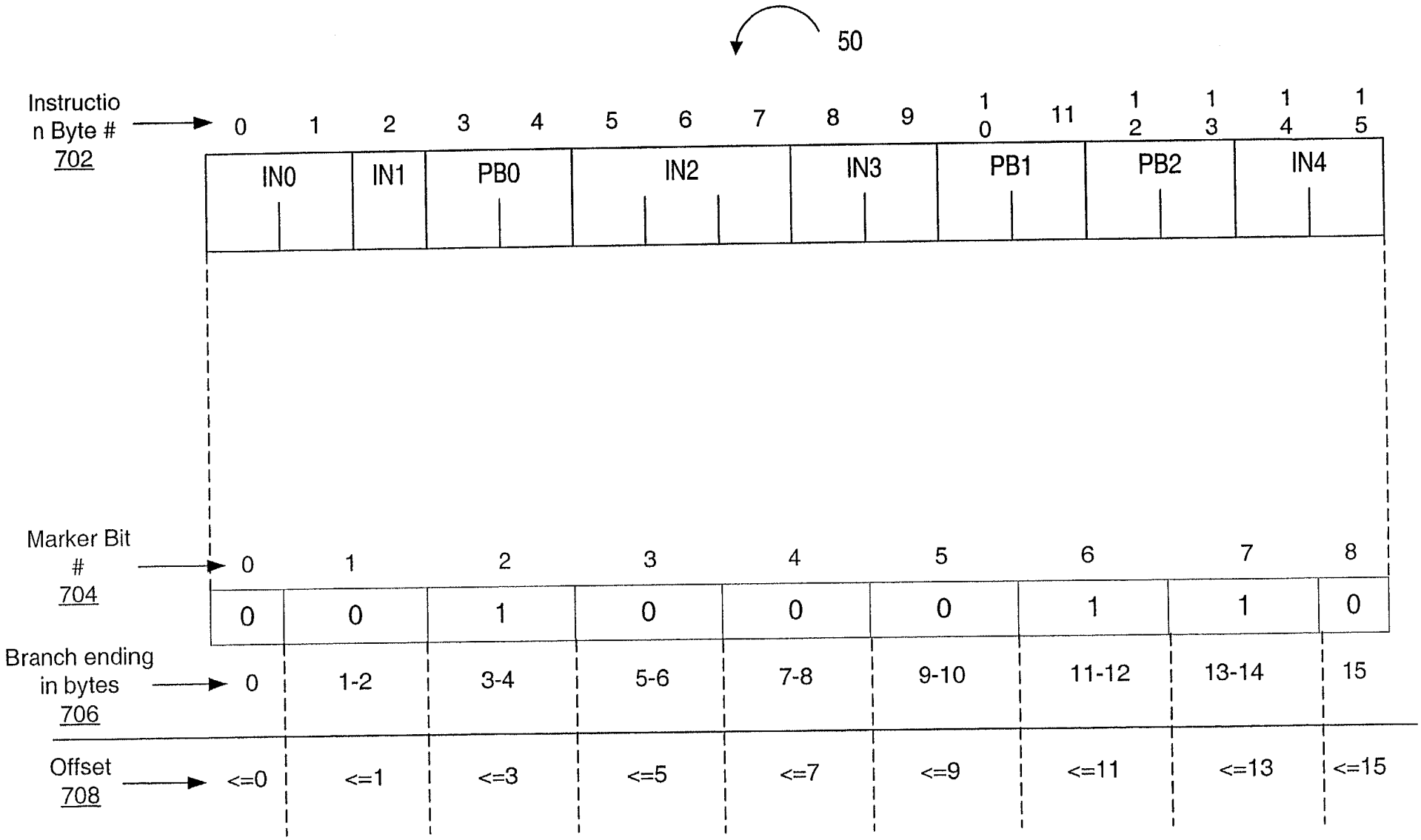

50
Instructio n Byte # 702
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
IN0
IN1
PB0
IN2
IN3
PB1
PB2
IN4
Marker Bit # 704
0 1 2 3 4 5 6 7 8
0 0 1 0 0 0 1 1 0
Branch ending in bytes 706
0 1-2 3-4 5-6 7-8 9-10 11-12 13-14 15
Offset 708
<=0 <=1 <=3 <=5 <=7 <=9 <=11 <=13 <=15

Fig. 7

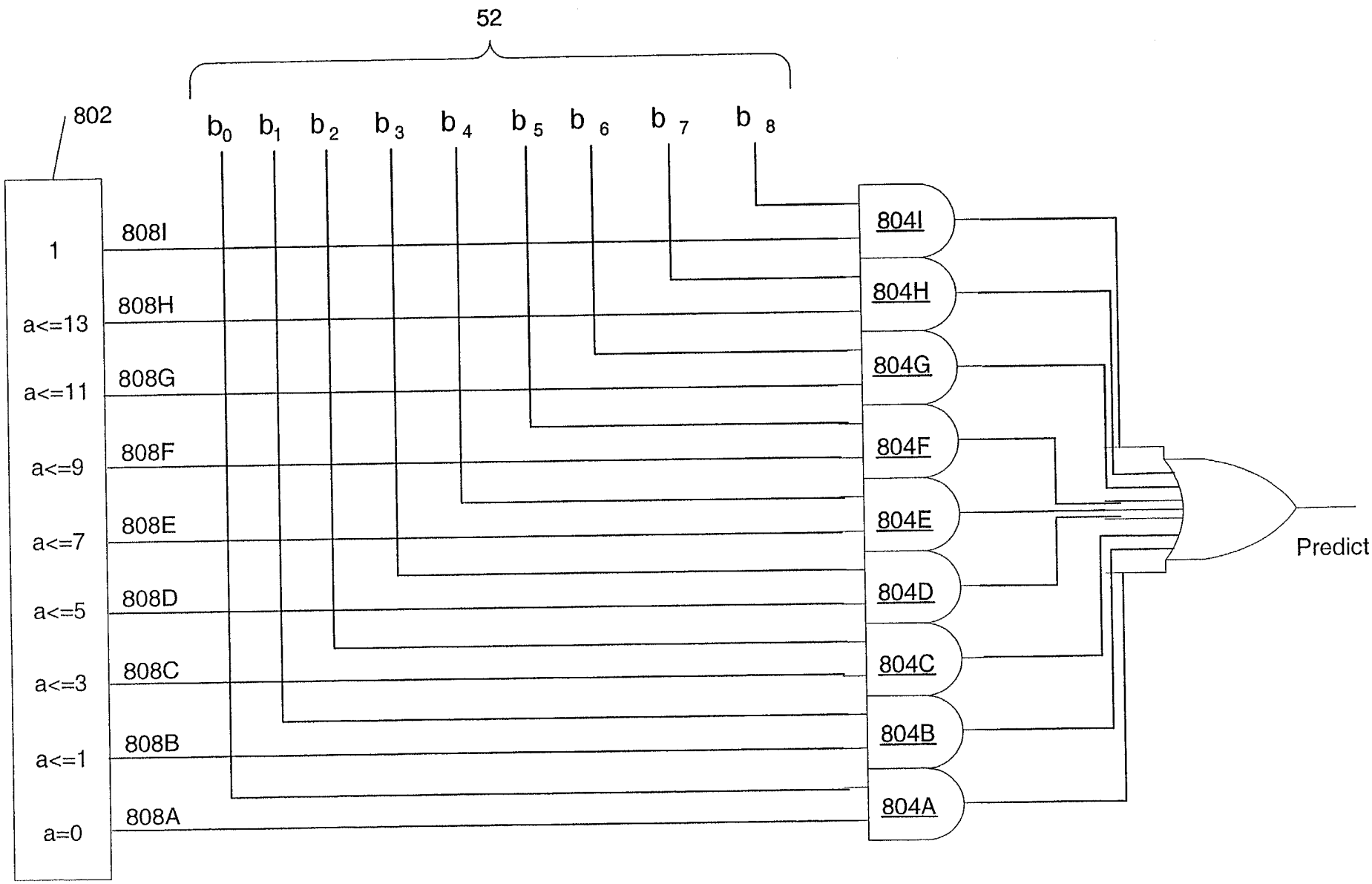

52
802
b_0 b_1 b_2 b_3 b_4 b_5 b_6 b_7 b_8
1
a<=13
a<=11
a<=9
a<=7
a<=5
a<=3
a<=1
a=0
808I
808H
808G
808F
808E
808D
808C
808B
808A
804I
804H
804G
804F
804E
804D
804C
804B
804A
Predict

Fig. 8

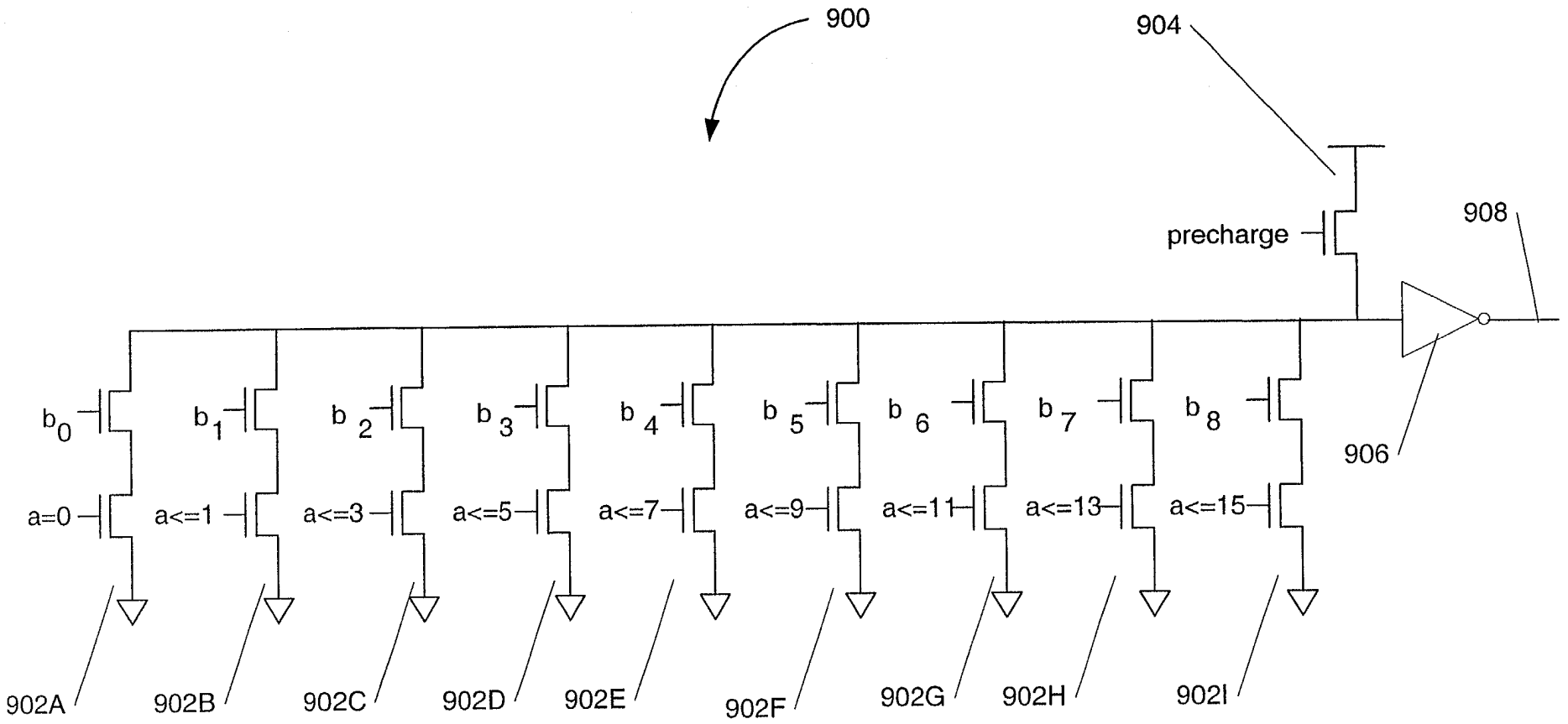

900
904
precharge
908
906
b0
b1
b2
b3
b4
b5
b6
b7
b8
a=0
a<=1
a<=3
a<=5
a<=7
a<=9
a<=11
a<=13
a<=15
902A
902B
902C
902D
902E
902F
902G
902H
902I

Fig. 9

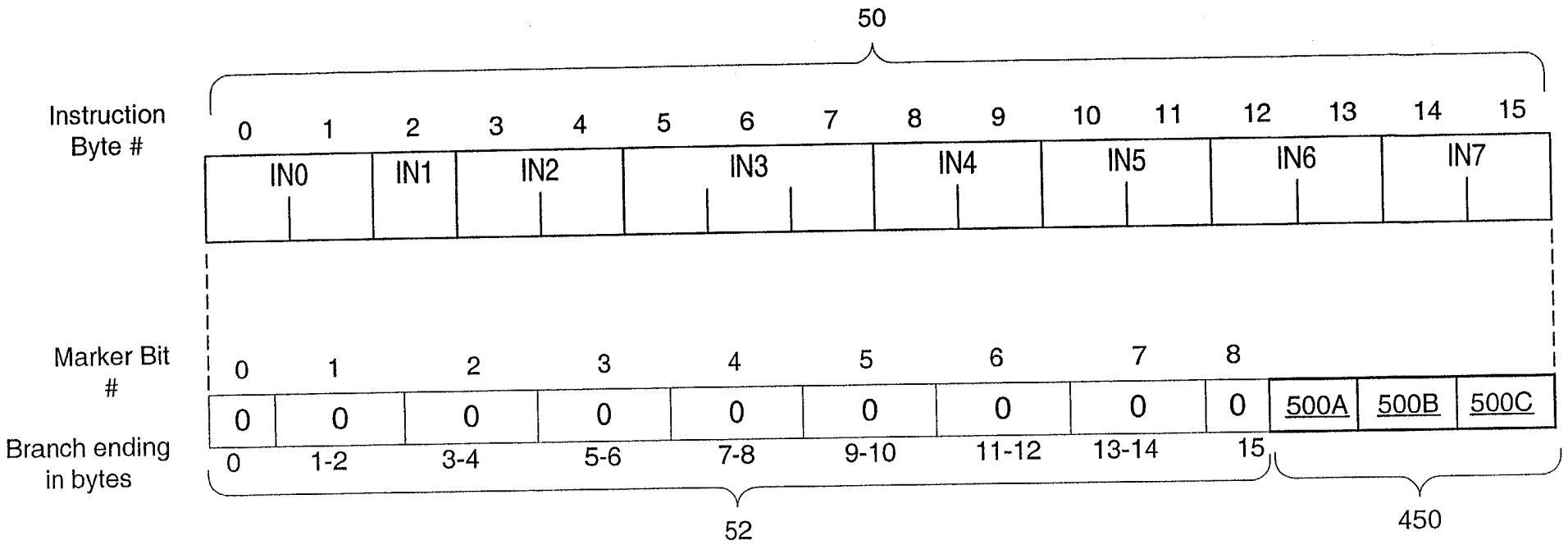


Fig. 10

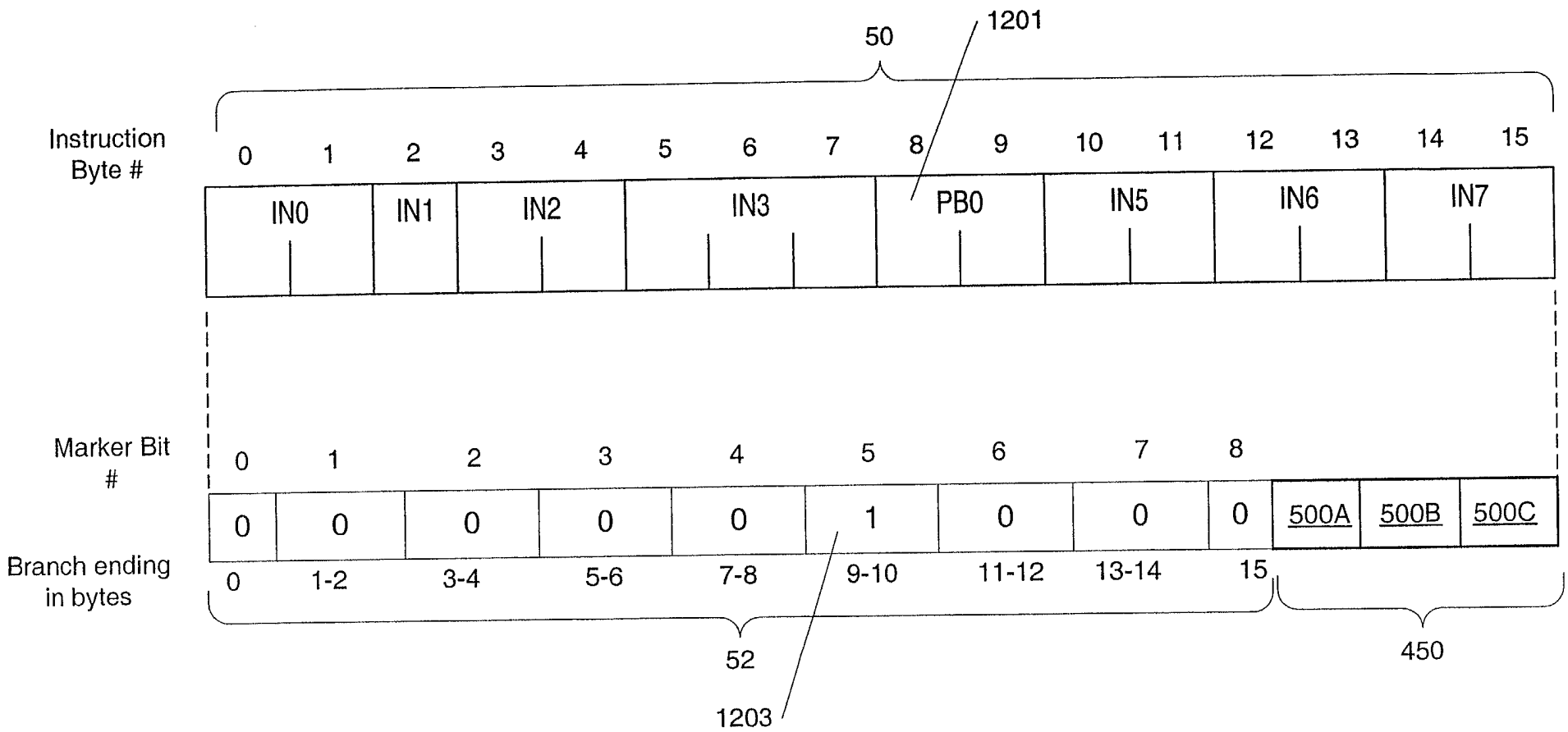


Fig. 11

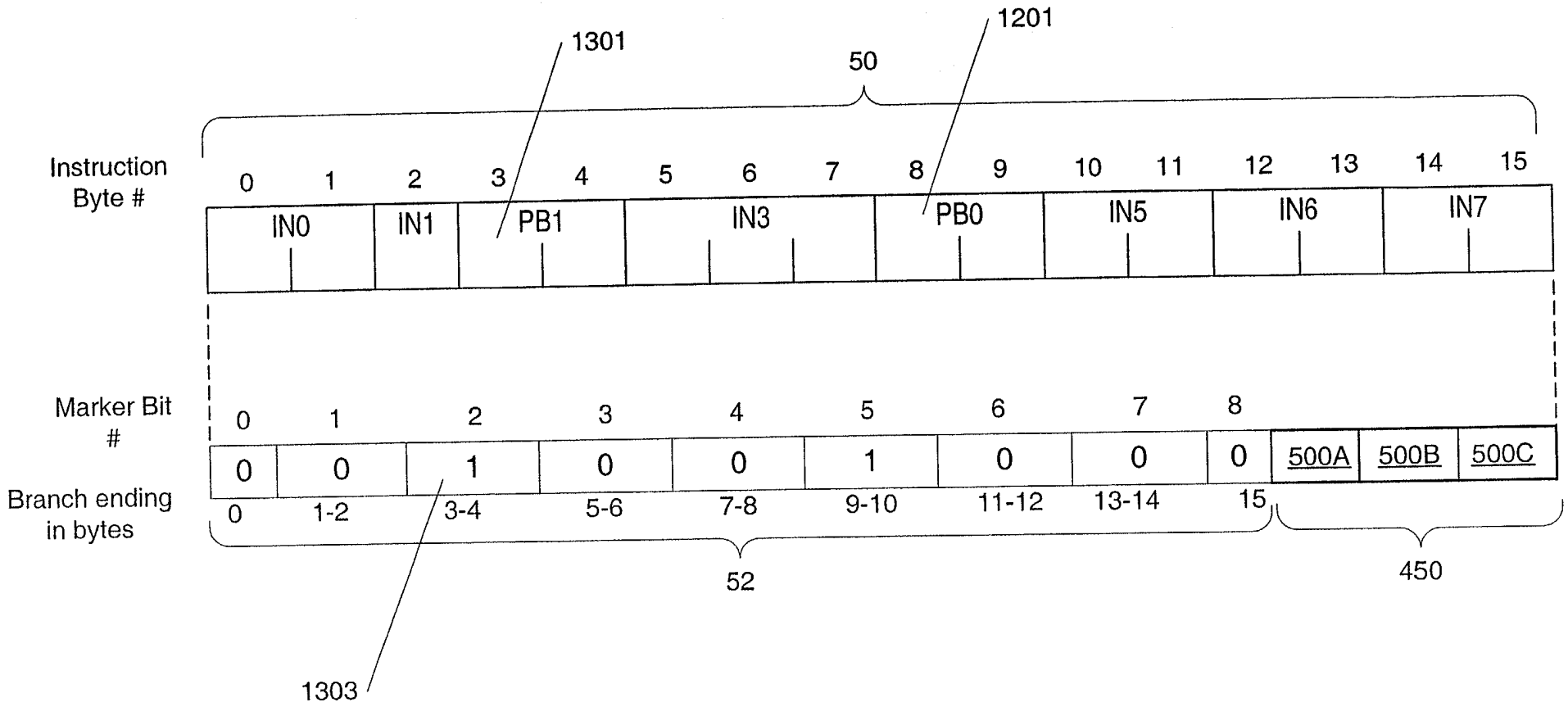
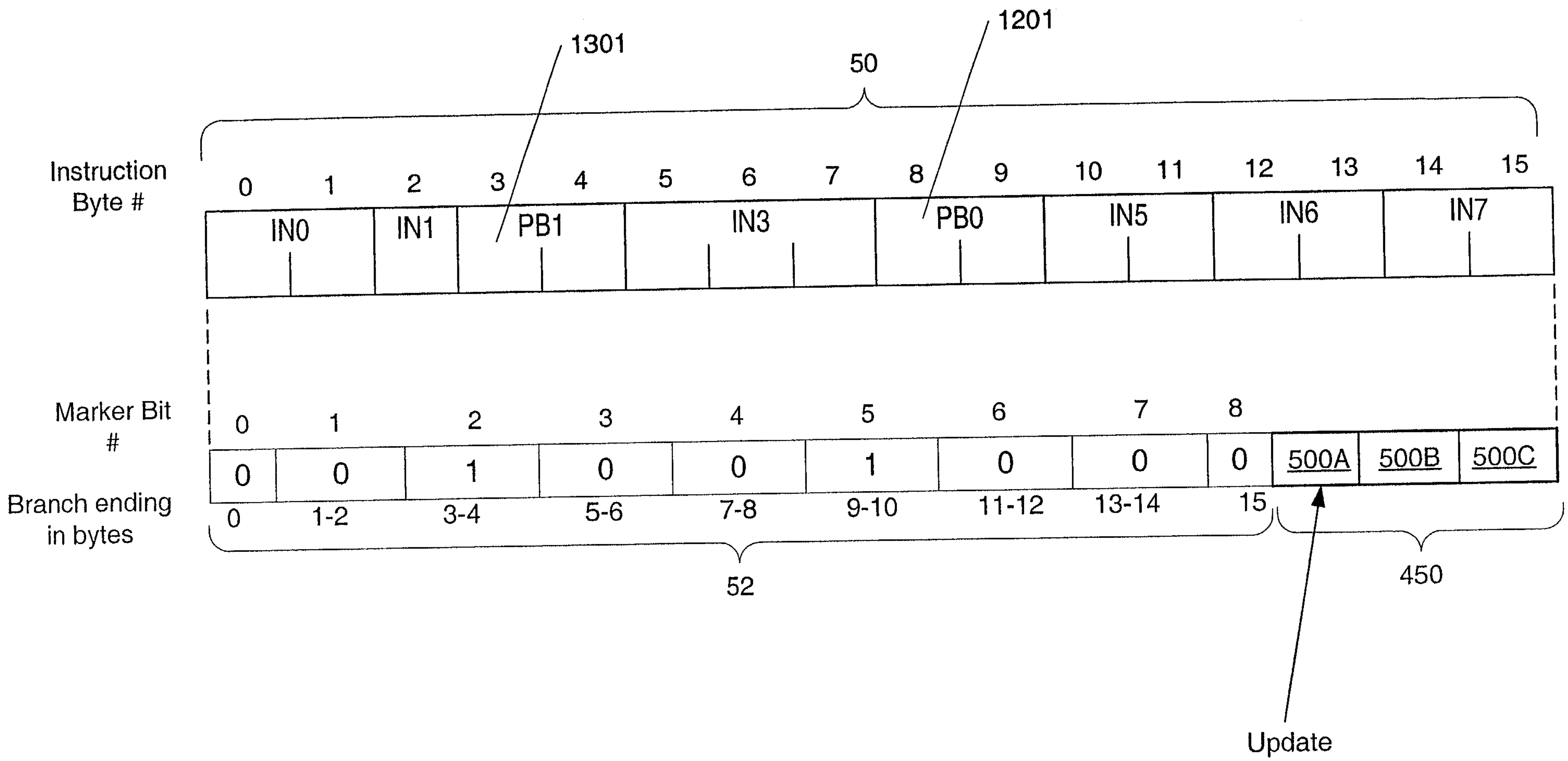


Fig. 12



Instruction Byte #
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
IN0
IN1
PB1
IN3
PB0
IN5
IN6
IN7
1301
1201
50
Marker Bit #
0
0
1
0
0
1
0
0
0
500A
500B
500C
Branch ending in bytes
0
1-2
3-4
5-6
7-8
9-10
11-12
13-14
15
52
450
Update

Fig. 13

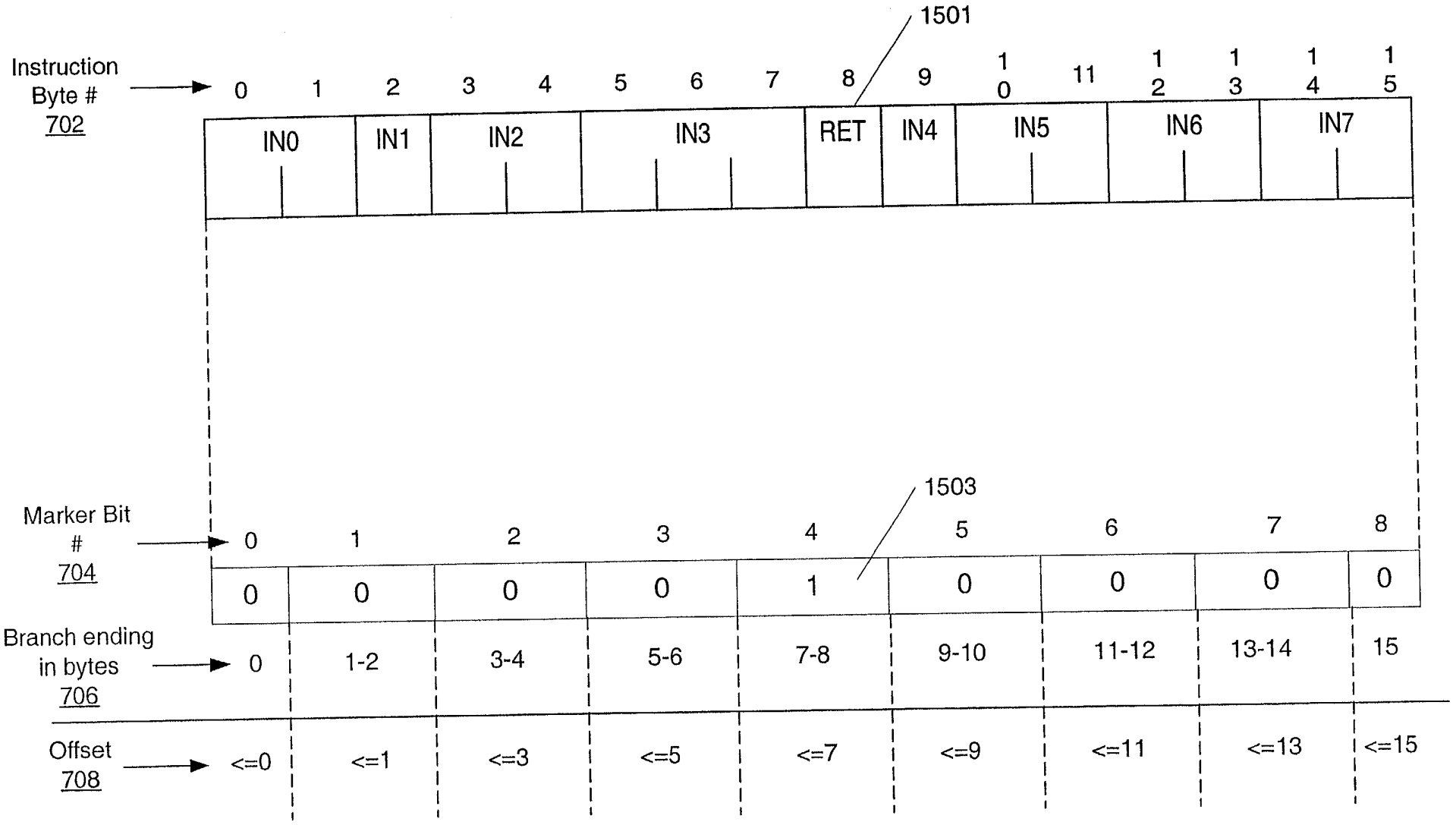
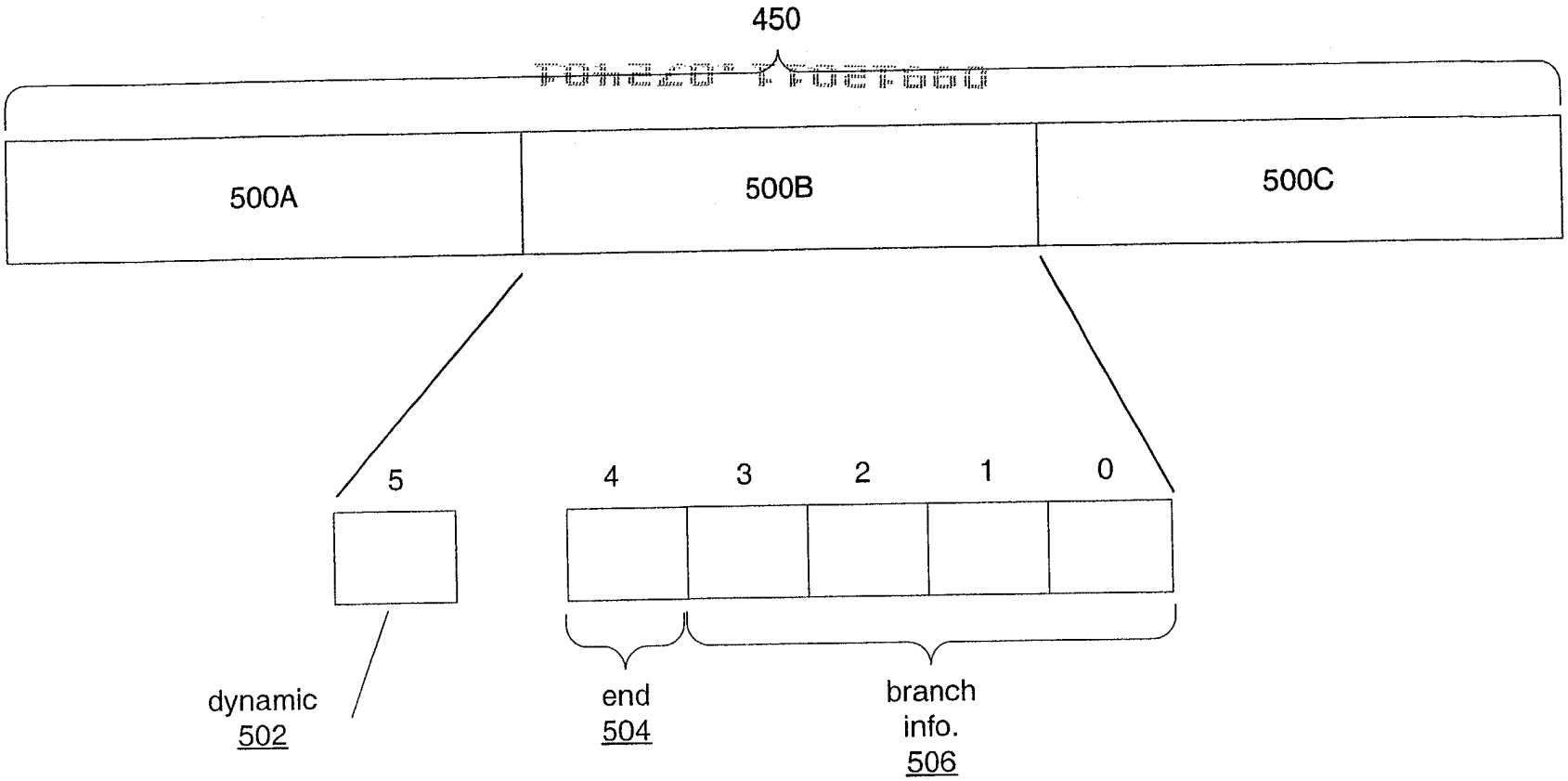

1501
Instruction Byte # 702
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
IN0
IN1
IN2
IN3
RET
IN4
IN5
IN6
IN7
1503
Marker Bit # 704
0 1 2 3 4 5 6 7 8
0 0 0 0 1 0 0 0 0
Branch ending in bytes 706
0
1-2
3-4
5-6
7-8
9-10
11-12
13-14
15
Offset 708
<=0
<=1
<=3
<=5
<=7
<=9
<=11
<=13
<=15

Fig. 14


450
500A
500B
500C
5
4
3
2
1
0
dynamic
502
end
504
branch
info.
506

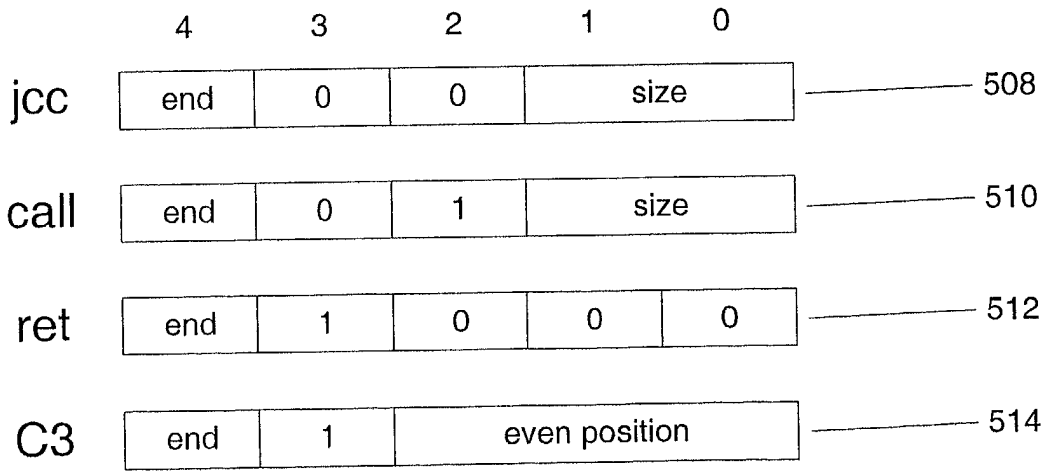

4
3
2
1
0
jcc
end
0
0
size
508
call
end
0
1
size
510
ret
end
1
0
0
0
512
C3
end
1
even position
514

Fig. 15

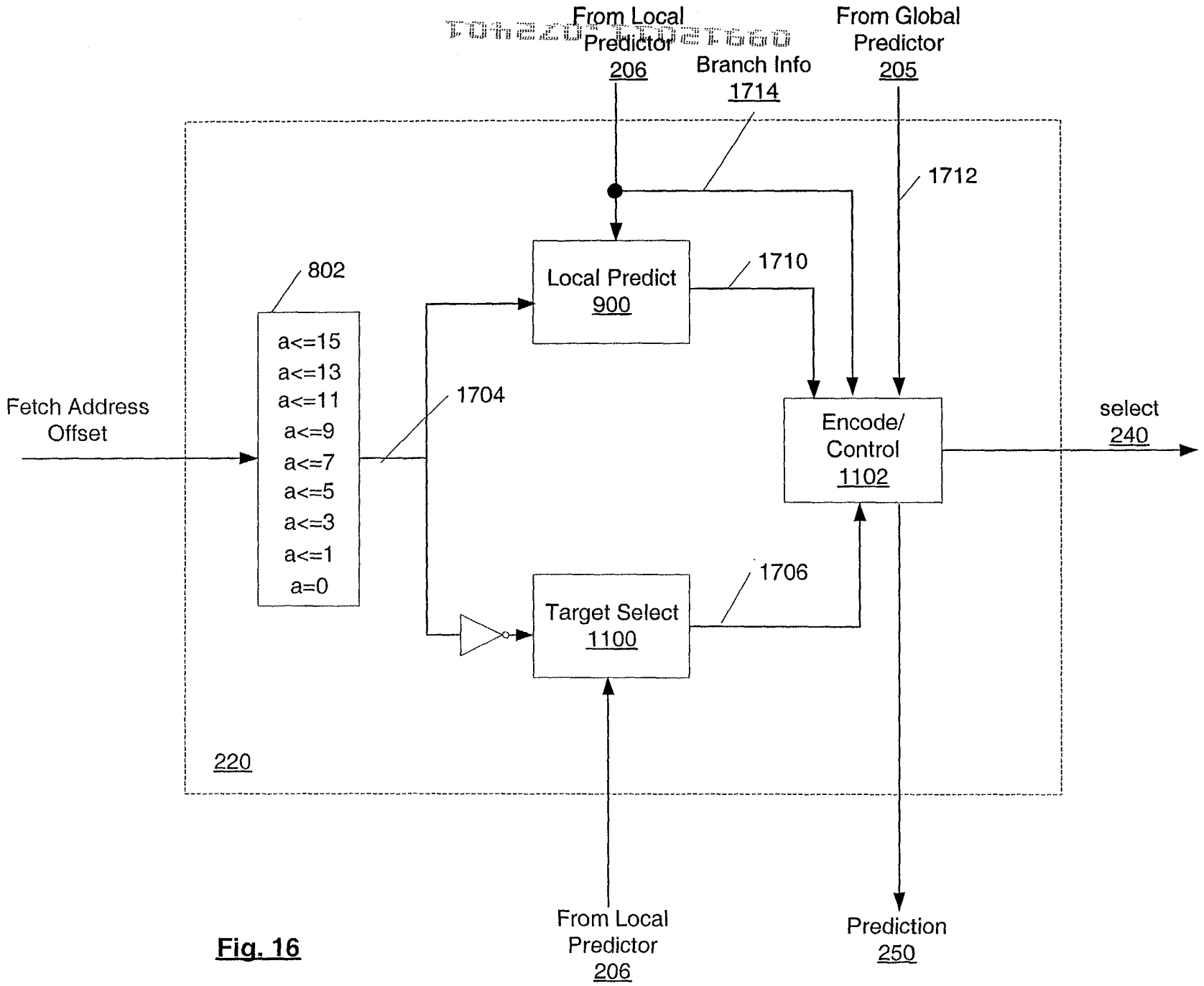

From Local Predictor 206
Branch Info 1714
From Global Predictor 205
1712
802
Local Predict 900
1710
a<=15
a<=13
a<=11
a<=9
a<=7
a<=5
a<=3
a<=1
a=0
1704
Fetch Address Offset
Encode/ Control 1102
select 240
1706
Target Select 1100
220
From Local Predictor 206
Prediction 250

Fig. 16

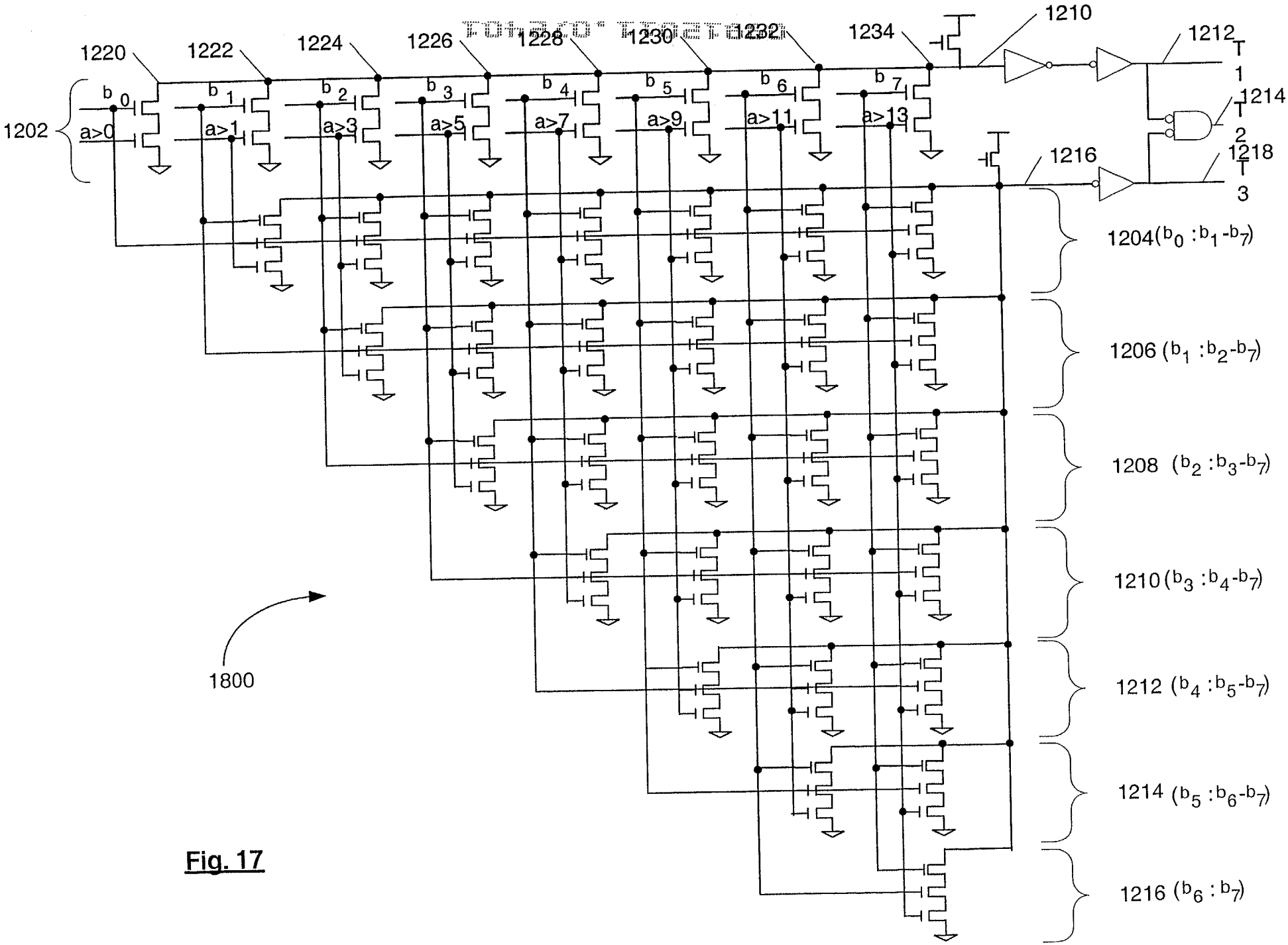

1220
1222
1224
1226
1228
1230
1232
1234
1210
1212
T 1
1214
T 2
1218
T 3
1216
1202
a>0
a>1
a>3
a>5
a>7
a>9
a>11
a>13
1204(b_0 :b_1-b_7)
1206 (b_1 :b_2-b_7)
1208 (b_2 :b_3-b_7)
1210 (b_3 :b_4-b_7)
1212 (b_4 :b_5-b_7)
1214 (b_5 :b_6-b_7)
1216 (b_6 : b_7)
1800

Fig. 17

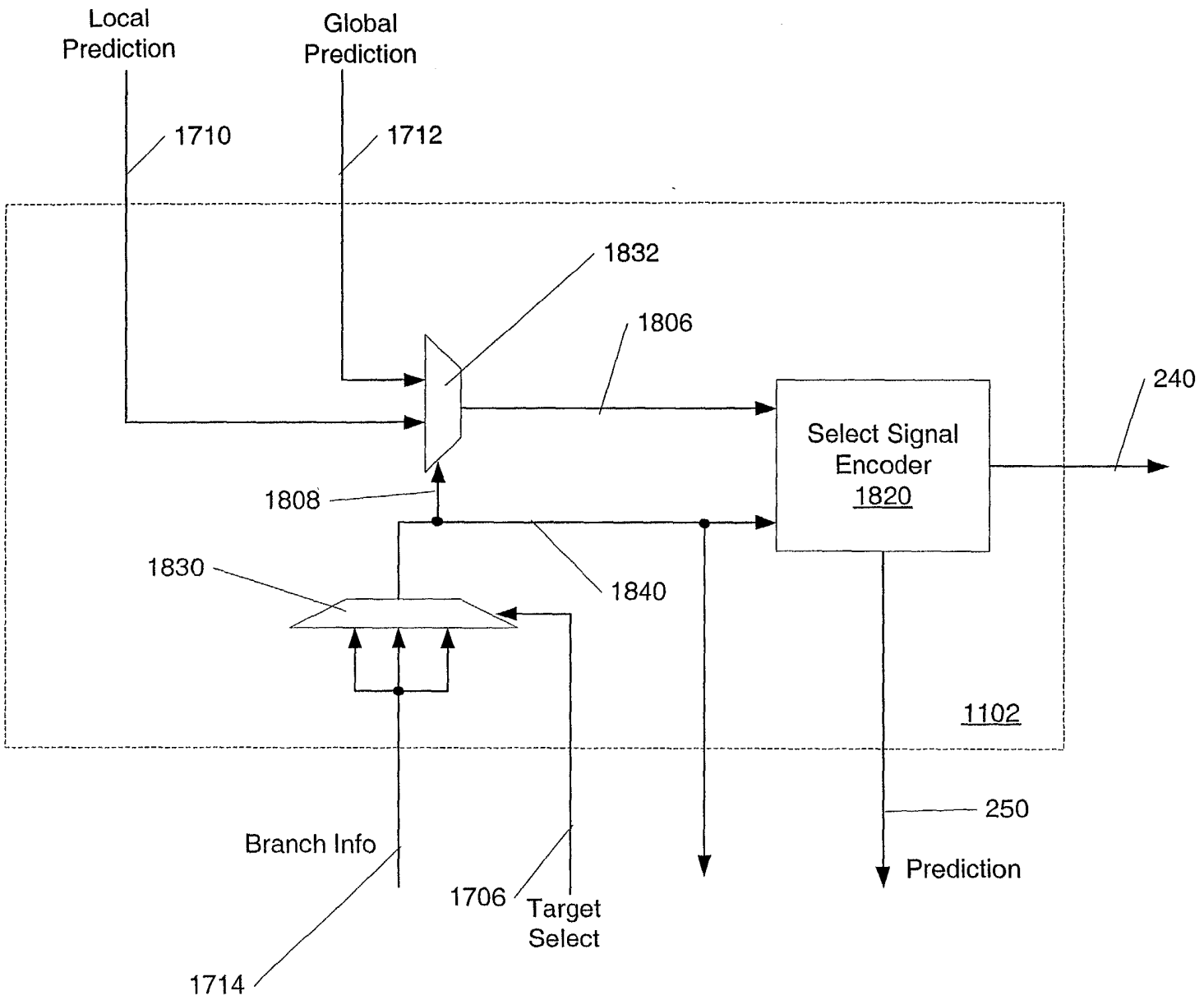

Local Prediction
Global Prediction
1710
1712
1832
1806
240
Select Signal Encoder 1820
1808
1830
1840
1102
250
Prediction
Branch Info
1706
Target Select
1714

Fig. 18

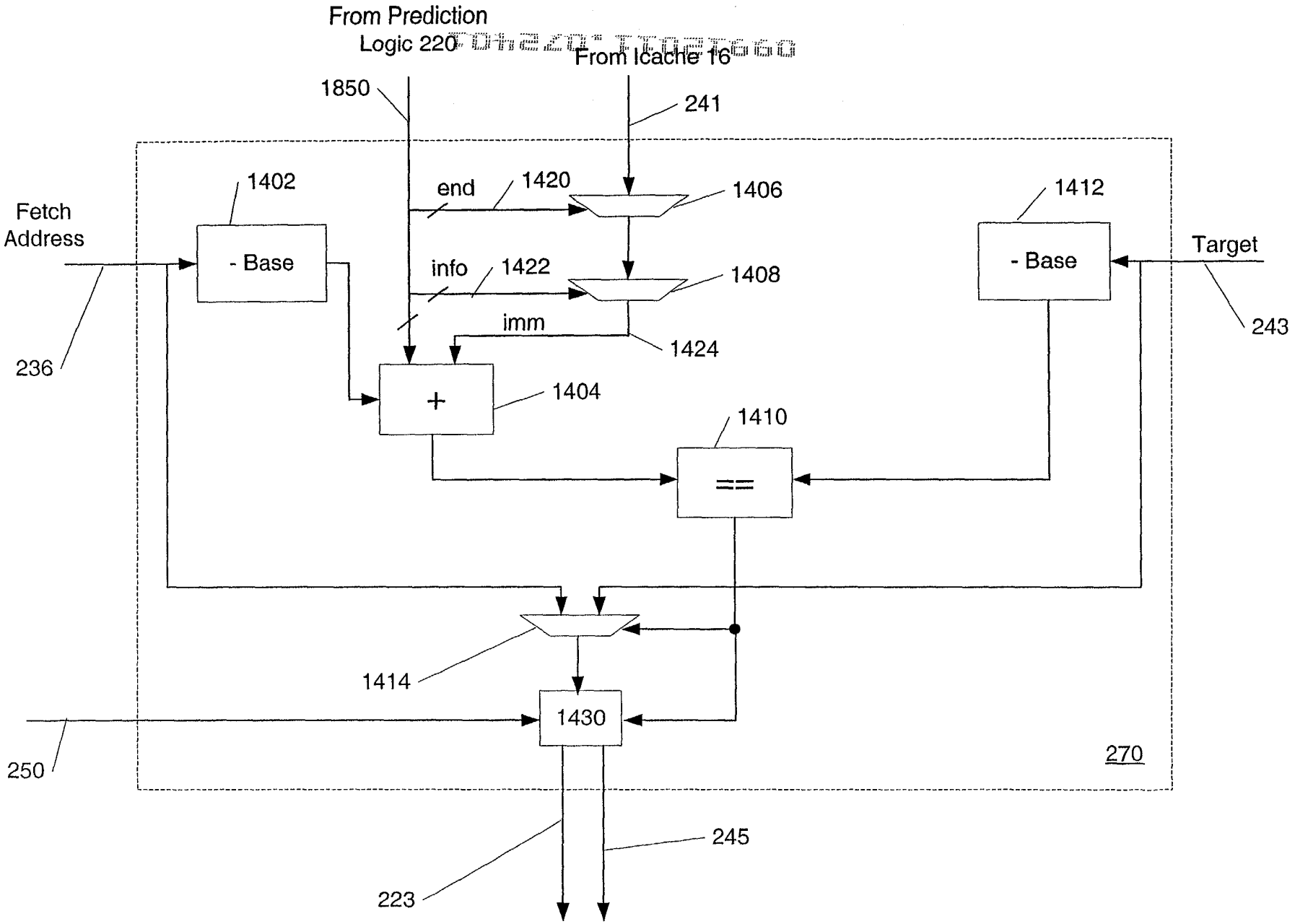

From Prediction Logic 220
From Icache 16
1850
241
1402
end
1420
1406
1412
Fetch Address
- Base
info
1422
1408
- Base
Target
imm
1424
236
243
+
1404
1410
==
1414
1430
250
270
245
223

Fig. 19

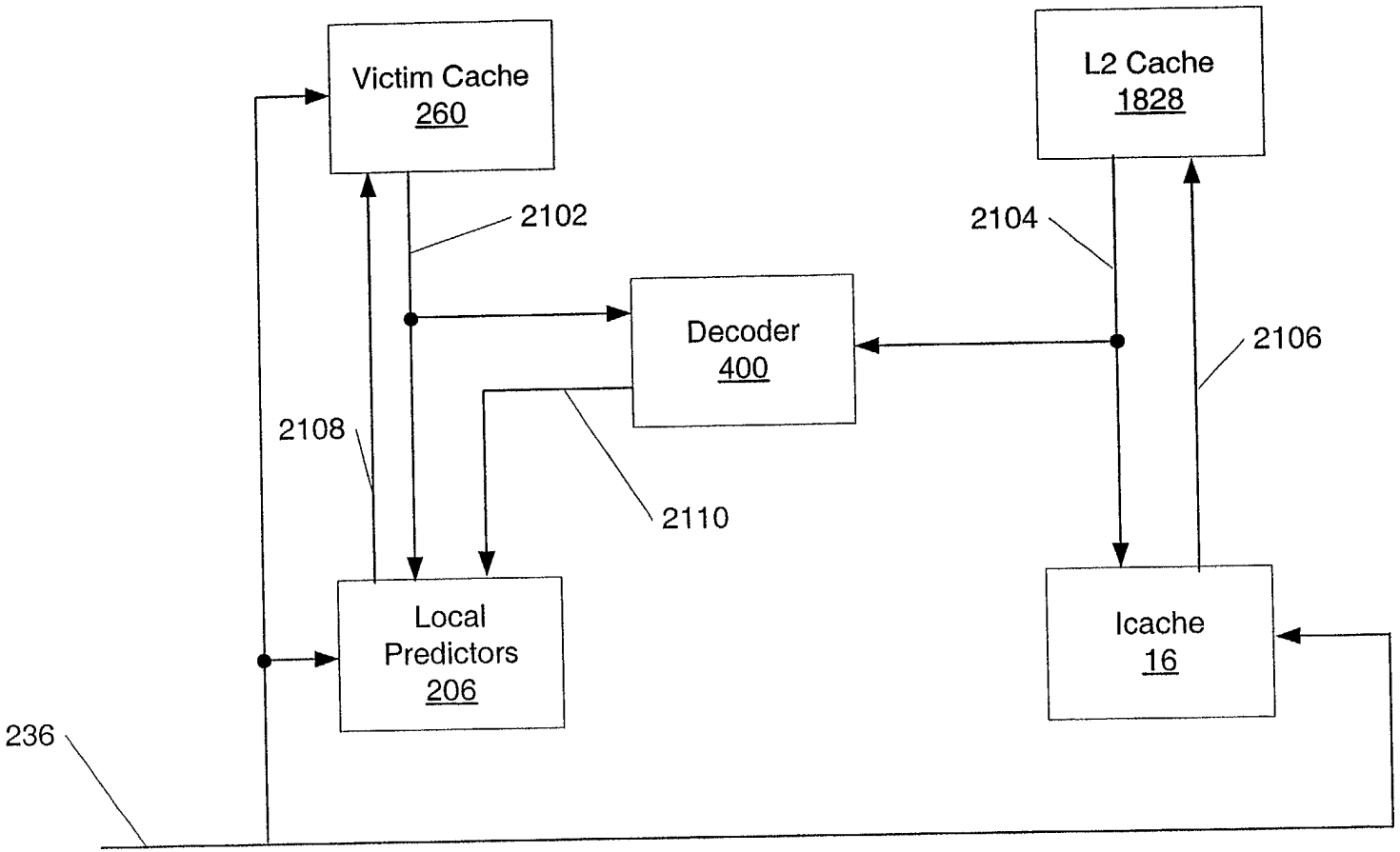

Victim Cache
260
L2 Cache
1828
2102
2104
Decoder
400
2106
2108
2110
Local
Predictors
206
Icache
16
236

Fig. 20

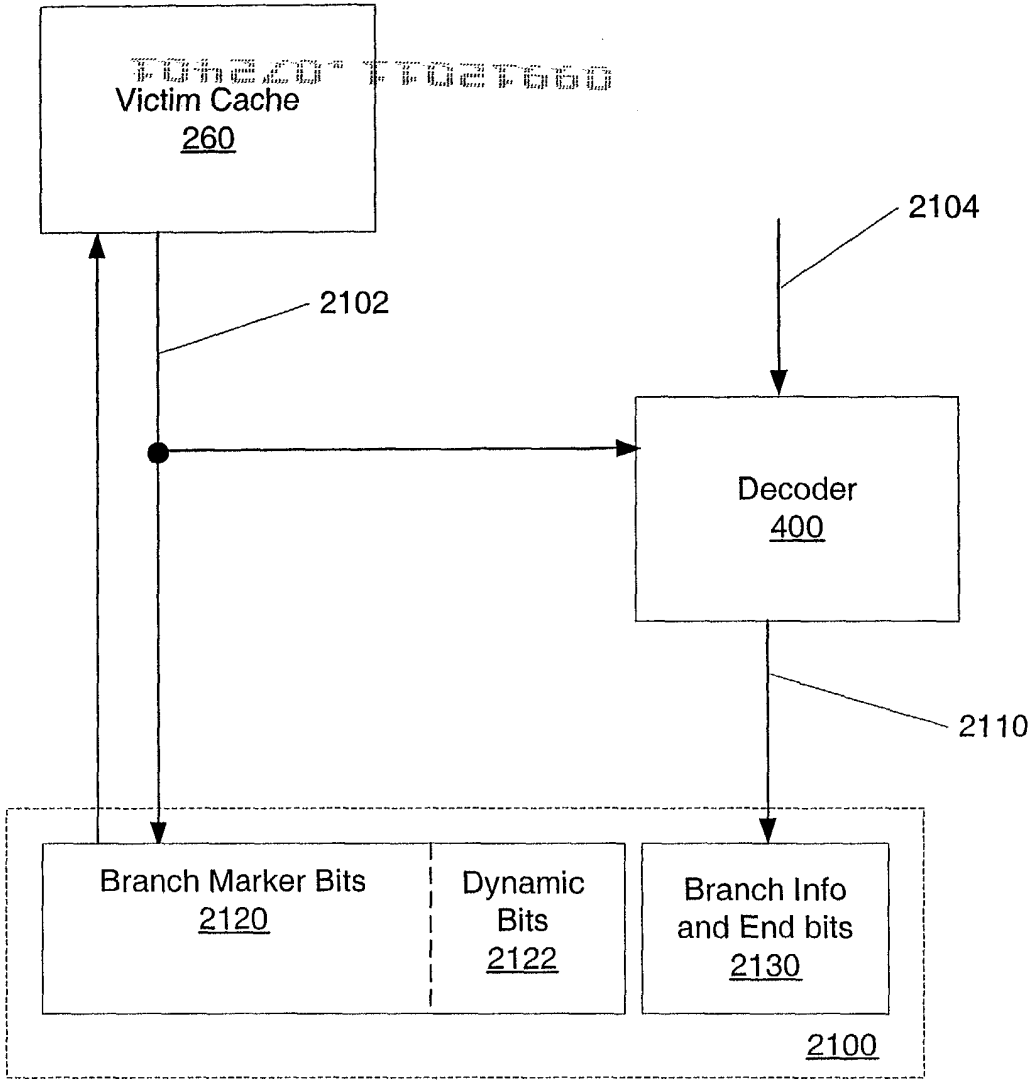

Victim Cache
260
2104
2102
Decoder
400
2110
Branch Marker Bits
2120
Dynamic
Bits
2122
Branch Info
and End bits
2130
2100

Fig. 21

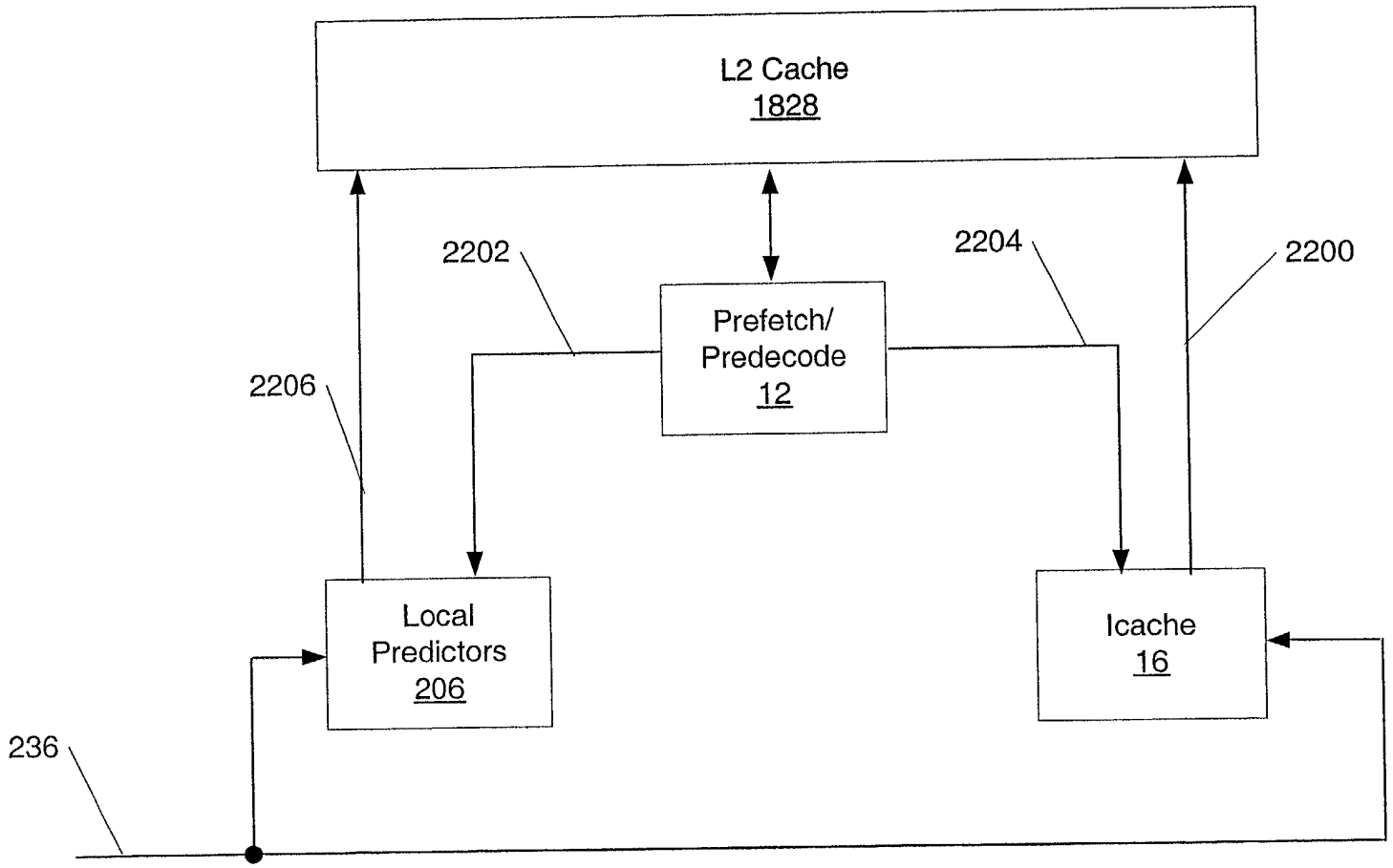


Fig. 22

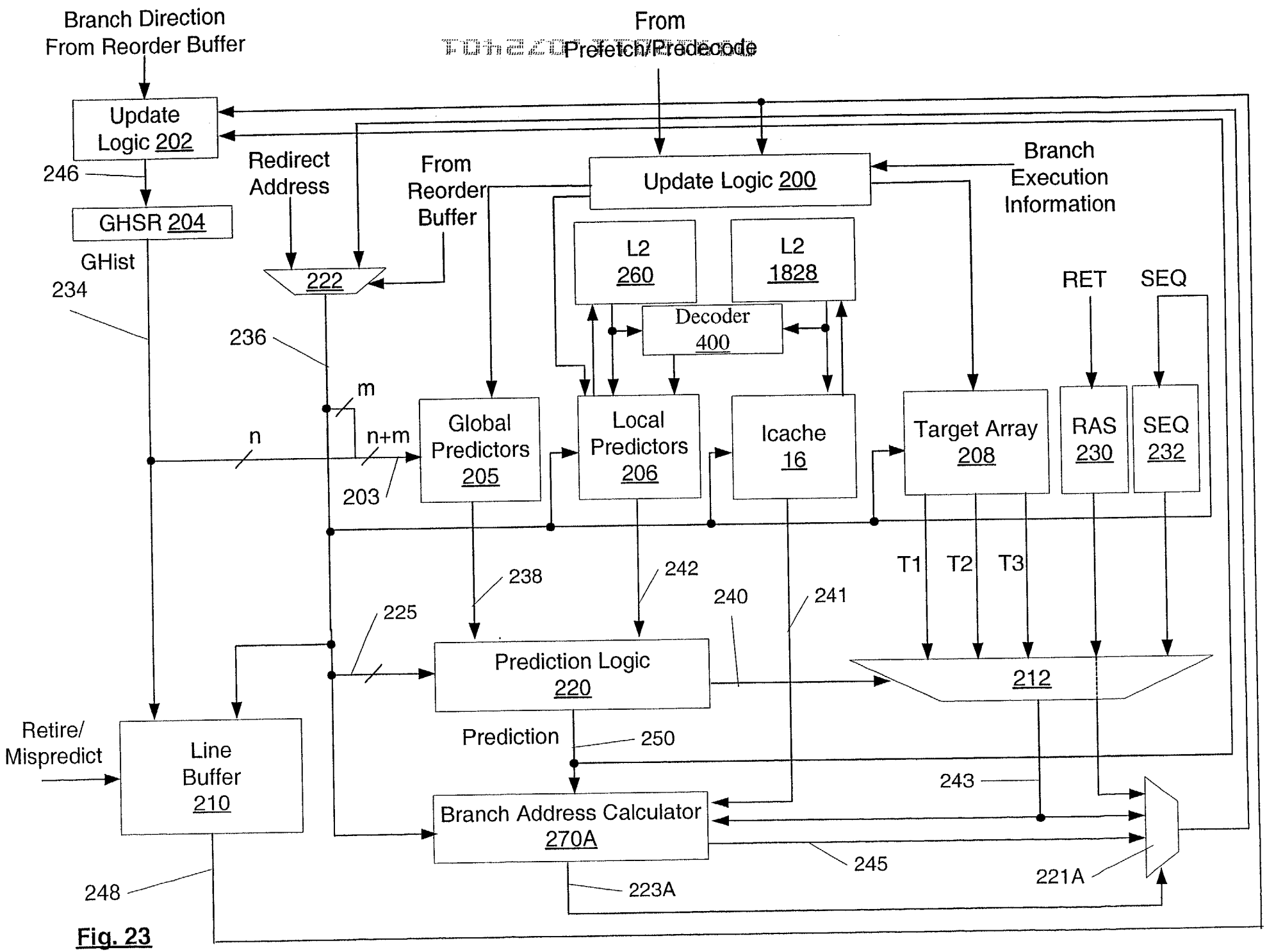

Branch Direction From Reorder Buffer
From Prefetch/Predecode
Update Logic 202
246
GHSR 204
GHist
234
Redirect Address
From Reorder Buffer
222
Update Logic 200
Branch Execution Information
L2 260
L2 1828
Decoder 400
RET
SEQ
236
m
n
n+m
203
Global Predictors 205
Local Predictors 206
Icache 16
Target Array 208
RAS 230
SEQ 232
T1
T2
T3
238
242
240
241
225
Prediction Logic 220
212
Retire/ Mispredict
Line Buffer 210
Prediction
250
243
Branch Address Calculator 270A
245
221A
248
223A

Fig. 23

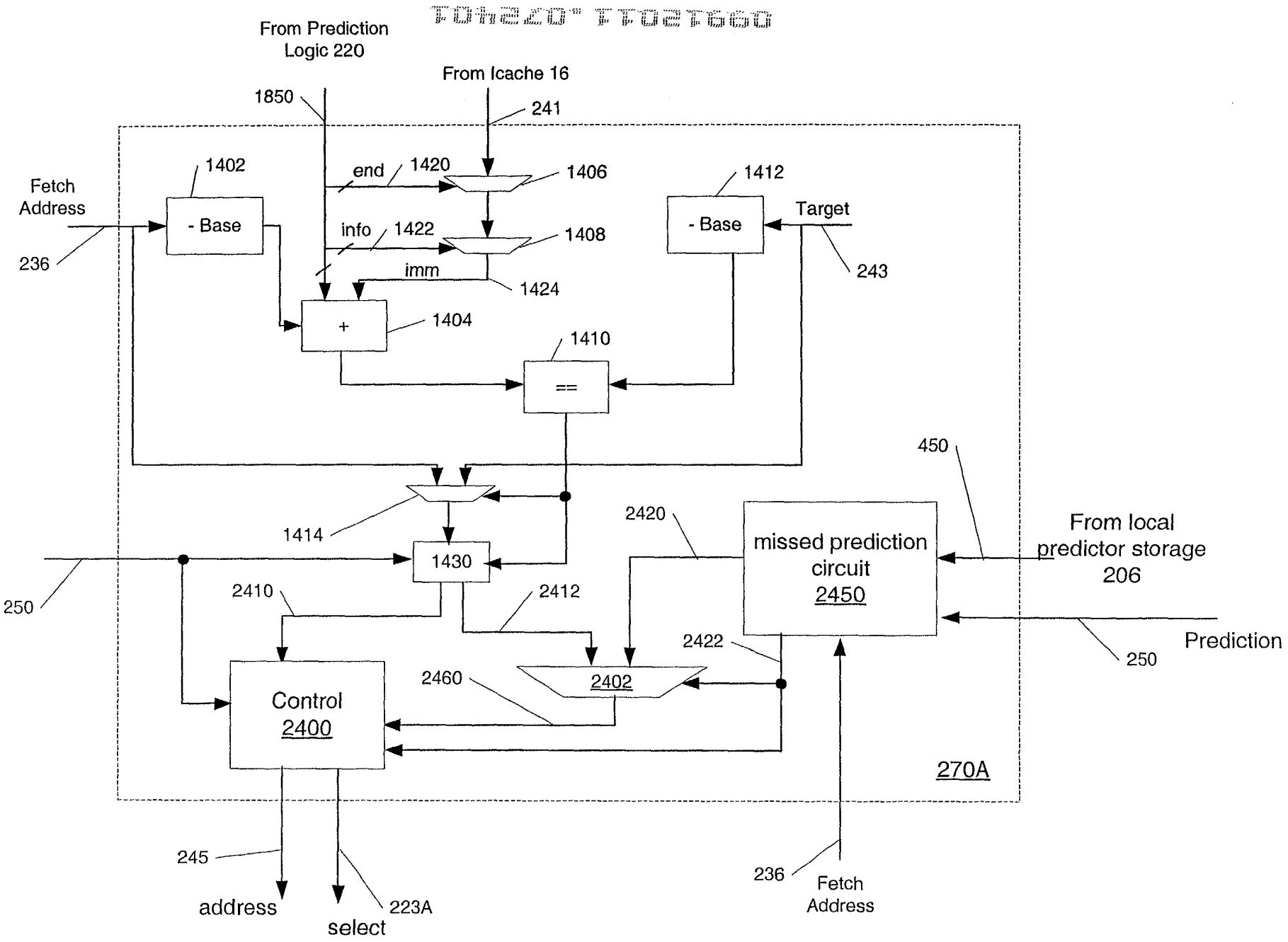

From Prediction Logic 220
From Icache 16
1850
241
1402
end
1420
1406
1412
Fetch Address
- Base
info
1422
1408
- Base
Target
236
243
imm
1424
+
1404
1410
==
450
1414
2420
missed prediction circuit 2450
From local predictor storage 206
1430
250
2410
2412
2422
Prediction
250
2460
2402
Control 2400
270A
245
address
select
223A
236
Fetch Address

Fig. 24

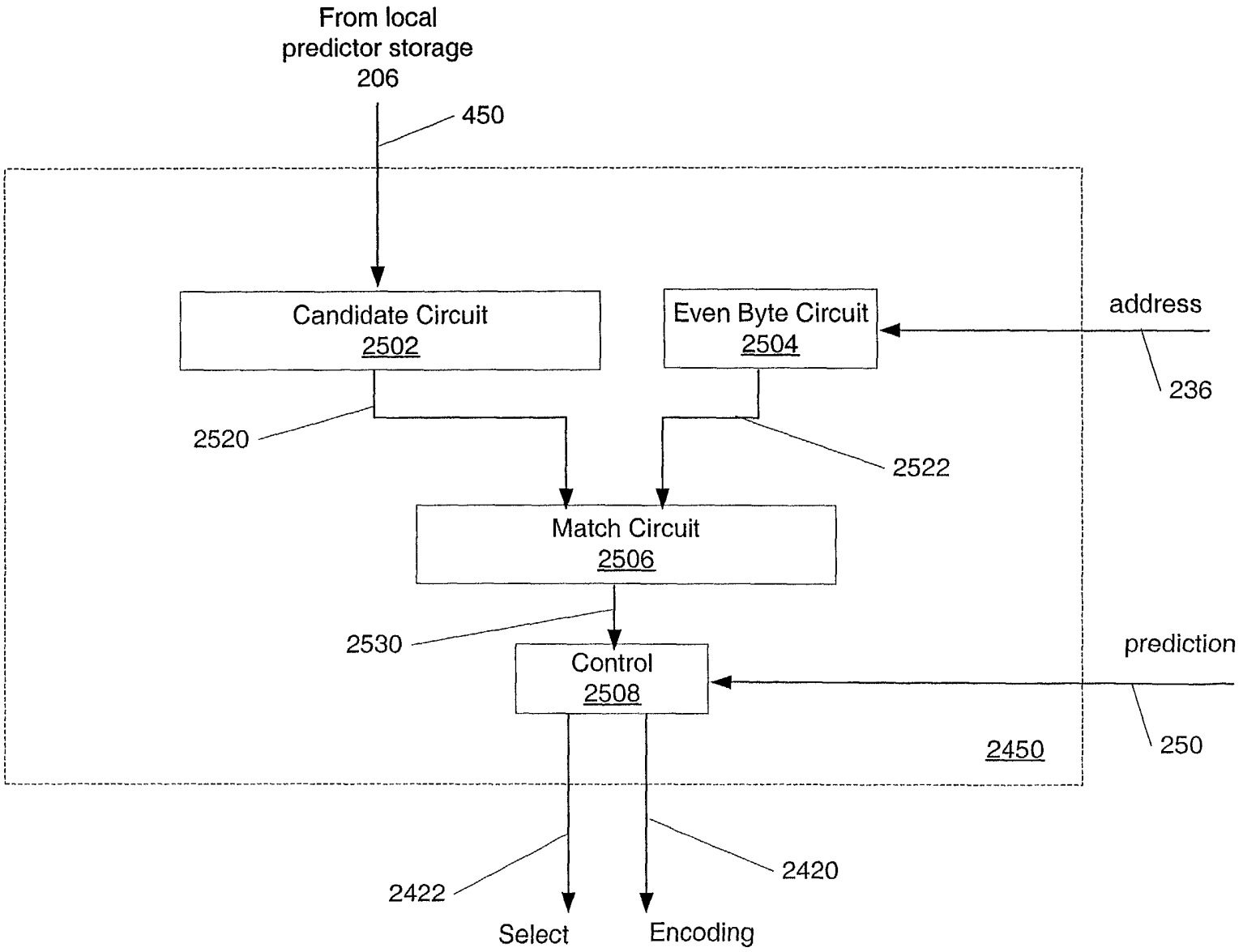

From local predictor storage 206
450
Candidate Circuit 2502
Even Byte Circuit 2504
address
236
2520
2522
Match Circuit 2506
2530
Control 2508
prediction
250
2450
2422
2420
Select
Encoding

Fig. 25

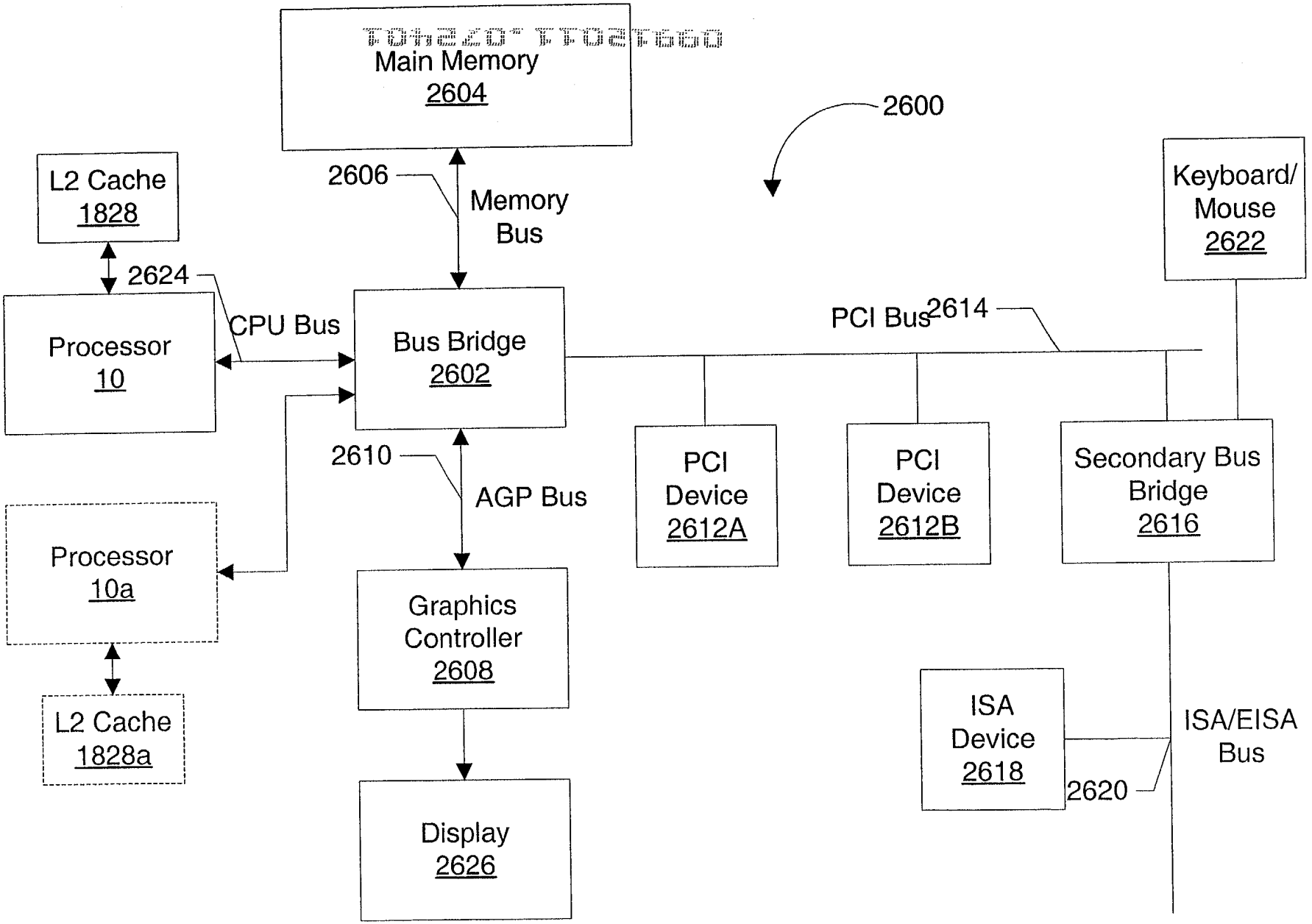

Main Memory
2604
2600
L2 Cache
1828
2606
Memory
Bus
Keyboard/
Mouse
2622
2624
Processor
10
CPU Bus
Bus Bridge
2602
PCI Bus
2614
2610
AGP Bus
PCI
Device
2612A
PCI
Device
2612B
Secondary Bus
Bridge
2616
Processor
10a
Graphics
Controller
2608
ISA
Device
2618
ISA/EISA
Bus
2620
L2 Cache
1828a
Display
2626

Fig. 26